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MAGNESIUM IN THE CASEIN-CONTAINING COLLOID OF MILK^{1/}

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INTRODUCTION

The magnesium content of milk, as reported in the literature, varies widely, from a minimum of 0.0092% to a maximum of 0.0236% (3, 11). There is also considerable variation in reported figures for the proportion of magnesium in milk that is insoluble, i.e., dispersed as part of the colloidal system. Reported proportions of non-dialyzable magnesium range from 13 to 38% of the total (1, 7) and of magnesium retained by the Pasteur-Chamberlain filter tube, from 8 to 34% of the total (11). De Kadt and Van Minnen, however, found appreciably less variation in the magnesium content of milk and in the proportion of the total magnesium that is removed as part of the colloid system by centrifugation (3). Although these authors suggested that the magnesium is being thrown out as magnesium citrate, Ford, et al. (5) considered the centrifugable magnesium to be part of the calcium-caseinate-calcium phosphate complex, and to be present in a molar concentration one-fifteenth that of calcium.

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The work here reported was undertaken to determine more precisely the amount of magnesium removed by centrifugation, to check the calcium:magnesium ratio used by Ford et al., and to establish, if possible, whether the magnesium is present as a part of the casein complex or as magnesium citrate.

EXPERIMENTAL PROCEDURE

Sample Preparation: Two methods were employed for preparation of samples. In the first, the colloids were separated in a centrifuge having a large(50 ml) air-driven bowl rotor, twice redispersed in water and redeposited; these washed colloids were then analyzed for magnesium, calcium and citrate content. This separation and washing technique has been described elsewhere(5,8). Such washed colloids were first prepared by Ramsdell and Whittier(9) who, however, used a Sharples supercentrifuge for the separation.

The second method of preparation was the depletion technique described by Ford et al.(5), using the 50 ml. bowl rotor and analyzing progressively depleted liquid samples for calcium, magnesium and nitrogen.

Methods of Analysis: Magnesium was determined by the method described by Hunter(6), for plant materials. Citrate was determined by the method of Deysher and Holm(4), suspensions for analysis being prepared by soaking the washed colloid in N/30 NaOH. The methods used for nitrogen and calcium were those described in the paper by Ford et al.(5).

RESULTS

A summary of the analyses of double-washed complex is given in Table I. No citrate was detected in any of these double-washed colloids.

TABLE I

Results of analysis of various double-washed centrifugally deposited colloids.

Type of Milk	Calcium percent	Magnesium percent	Mol Ratio, Calcium:Magnesium
Jersey No. 1	2.55	0.131	11.7
Jersey No. 2	2.67	0.120	13.7
Jersey No. 3	2.90	0.120	14.5
Herd No. 1	2.81	0.110	15.3
Herd No. 2	2.69	0.101	16.0
Holstein No. 1	2.86	0.120	14.3
Holstein No. 2	2.72	0.096	17.0
Averages	2.74	0.114	14.6 ^a /

a/ This corresponds to a weight ratio of 24.0:1.

Figure 1 shows the relationship between calcium and magnesium content and nitrogen content on liquid samples as the colloids are progressively removed by centrifugation. It can be seen that both calcium and magnesium are being thrown out along with nitrogen in approximately constant ratios. The average mol ratio of calcium removed to magnesium removed given by the slopes of these lines is 12.4:1. In Figure 1 the values plotted are the differences between analyses on the original skim milk and on the centrifuged serums.

DISCUSSION

The mol ratios obtained for both deposits and serums are of the same order of magnitude as those calculated from the data of De Kadt and Van Minnen (3). They reported six analyses of skim

milks and corresponding centrifuged serums, from which mol ratios of 15.0 to 21.5 (average 18.3) can be calculated, and two analyses of unwashed deposits giving mol ratios of 18.2 and 15.6. Ford, Ramsdell, and Landsman (unpublished data) obtained the ratios 13.8 and 16.9 by analysis of unwashed and washed deposits.

De Kadt and Van Minnen's suggestion, that magnesium is thrown out as magnesium citrate, is neither supported nor completely ruled out by the present results. Their analyses were on unwashed deposits, and since our washed deposits give no test for citrate, but do contain magnesium, it must be concluded that such magnesium is not present as magnesium citrate. De Kadt and Van Minnen's unwashed deposits contain, however, more citrate than can be accounted for as citrate proportional to the entrained serum water. More elaborate experiments will be required to determine the condition of this excess citrate.

If milk averages 3% casein-containing colloid and the colloid is 0.114% magnesium, then milk contains 0.0033% magnesium associated with the colloid. Taking the total magnesium content to be 0.012% (based on data given in references 3 and 11, and on an average value of 0.011% given by analyses run in this laboratory), then about one-third of the magnesium in milk is in combination with the colloid. This compares with De Kadt and Van Minnen's 25% for the amount of the magnesium that is thrown out by centrifugation.

Reference has been made to data, reported by Van Slyke and Bosworth(11), on the amounts of calcium and magnesium retained

by Pasteur-Chamberlain filter tubes. These authors also give results of analysis of the original skim milks. Therefore, calcium to magnesium ratios for the retained colloids can be calculated from their data. Columns "2" and "3" of Table II are calculated from Table III of the article by Van Slyke and Bosworth. Column "4" is column "2" divided by column "3", and multiplied by the atomic weight factor, 24.3:40.1.

TABLE II

Calcium:magnesium ratios
for the
retained colloids
(Calculated from the data of Van Slyke and Bosworth)

Cow No.	1 Total Calcium Retained percent	2 of Total Magnesium Retained percent	3 of Total Magnesium Retained percent	4 Mol ratio Calcium:Magnesium in retained colloid
1	54	8		40.7
2	63	14		27.8
3	60	21		13.0
3	66	8		44.5
4	77	30		12.4
5	62	20		16.4
5	64	9		37.5
6	74	21		19.2
7	64	16		24.7
7	70	28		13.1
8	71	23		10.5
9	71	26		14.4
10	61	16		19.5
11	74	29		12.7
12	75	36		11.1
13	69	31		12.5

Noting that De Kadt and Van Ninnen's figures indicate 25% of the magnesium to be colloid-bound, that dialysis experiments (1,7) indicate 13 to 38%, and that our data indicate about 33%, it is suggested that, since Van Slyke and Bosworth's high calcium

to magnesium ratios always coincide with low retention of magnesium and of calcium by their filters, it is probable that in these cases the pores were too coarse to properly retain the casein-containing colloid. It is suggested, therefore, that these particular ratios can be ignored. The remaining results are much more consistent among themselves; and the indicated calcium:magnesium ratios at high retention values, are in good agreement with the results presented here.

In a recent article, Van Kreveld and Van Minnen(10) state that one-sixth of the magnesium in milk is present in ionic form. Christianson, Jenness, and Coulter(2), report 0.82 to 0.85 millimoles of magnesium ion in a liter of milk. Since there are, on the average, a total of about 5 millimoles of magnesium in a liter of milk, their figures also indicate that about one-sixth of the magnesium is present in the ionic form. Thus, subtracting one-sixth (present as ions) plus one-third (associated with the colloid) from the total, there remains about one-half of the magnesium in milk to be accounted for in some other form.

SUMMARY

It has been shown that about one-third of the magnesium in milk is present in the casein-containing colloid and that the calcium to magnesium mol ratio in the colloid is about 15:1.

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FIGURE LEGEND

Figure 1. Calcium and magnesium analysis of ultracentrifuged milk serums. Open circles indicate averages of two or three calcium determinations. Closed circles indicate averages of four or five magnesium determinations.



